Satellite Dynamics About Tri-Axial Ellipsoids

D.J. Scheeres
MS 301-125J
Jet Propulsion laboratory
California Institute of Technology
Pasadena, California 91109
(818) 354-7128
email: djs@leelanau.jpl.nasa.gov

Current planning for the Near Earth Asteroid Rendezvous (NEAR) mission includes an orbital phase about an asteroid. The current mission design stipulates Eros as the target asteroid. For science purposes it is desired to orbit the asteroid as closely and as safely as possible for an extended period of time (100+ days). However, due to the extremely distorted shape of Eros ($\approx$ 40 x 14 x 14 km), satellite orbits are significantly non-Keplerian and include, among others, crashing, escaping and stable orbits, all starting with local circular velocity and zero eccentricity.

We model Eros as a constant density, uniformly rotating tri-axial ellipsoid. The potential field of such a body and its gradients may be computed using the classical result of Ivory's theorem. Given this system, it is possible to discuss a variety of interesting classes of orbits about the body. We first discuss some general results on synchronous, circular orbits about a rotating ellipsoid. This discussion leads directly to a characterization of when crashing/escaping or stable orbits exist about an ellipsoid. Then, for the specific asteroid Eros, we compute families of planar and out-of-plane periodic orbits. The out-of-plane periodic orbits are especially interesting.

Finally, we investigate possible simplifications to the general dynamical system. These allow us to describe the tri-axial ellipsoid in terms of the J_2 and J_3 parameters. These provide simple analytic expressions for the secular variation of a satellite's orbital elements. It is noted that these secular variations can be quite large, leading to satellite motion which is significantly non-Keplerian.

We believe that the study of satellite motion about general tri-axial ellipsoids is a significant topic. First, as many upcoming spatial-scientific missions will be orbiting small bodies with non-spheroid shapes. Second, as this is a non-trivial, non-integrable open problem in astrodynamics. This paper will serve as an introduction to this problem and present some basic results and methods of study for this problem.